Spring 2019

The Applications of Grid Cells in Computer Vision

Keaton Kraiger
Portland State University

Maseeh College of Engineering and Computer Science
PORTLAND STATE UNIVERSITY

The Applications of Grid Cells in Computer Vision

Keaton Kraiger, Prof. Dan Hammerstrom, Portland State University

C-BRIC Center for Brain Inspired Computing

INTRODUCTION

- Grid cells are neurons that become active at multiple locations in an environment.
- A grid cell module is a collection of grid cells that activate with the same lattice spacing and orientation [2], Figure 1A.

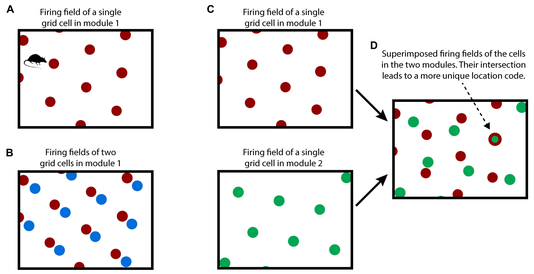
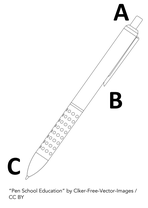


Figure 1. How grid cells represent location [1] by Numenta / CC BY.

- As an animal moves in a space, active grid cell modules update to reflect the animal's new position.
- A single grid cell module is unable to represent location due to its repeating nature.
- Unique locations can be represented by multiple grid cell modules, Figure 1D.
- Objects can be defined as a collection of unique locations.
- These collections of locations allow grid cell modules to represent objects.

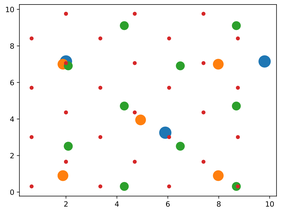


"Pen School Education" by Clker-Free-Vector-Images / CC BY

- **Research Question**: Can grid maps represent and retain enough information about an object to identify and classify it while still maintaining position and scale invariance?

METHODOLOGY

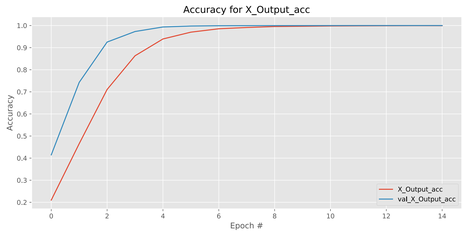
- Generate an image dataset of different potential grid maps, each representing an x-y location in a 9x9 Euclidian grid.



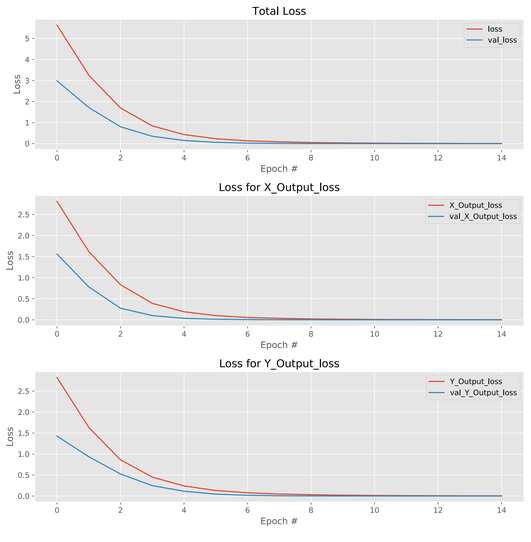
- Classify grid map x-y representations using a convolutional neural network.
- The network is a multi-output classifier with two fully-connected heads where one fork is responsible for classifying the x position and the other for y position.
- Generate objects by placing straight lines between x-y locations obtained from grid map representations.

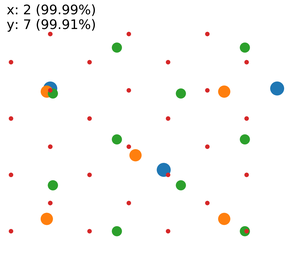
FINDINGS

- Given an image of a grid map, the model was able to reach ~99.3% accuracy for predicting x values and ~99.1% for predicting y values on average.



- Accuracy is the ratio of number of correct predictions to the total number of input samples.
- The model learned to predict x values faster and more accurately than y values.
- Loss is a measurement of how accurately the algorithm models the given data.
- After four epochs, the x value output loss was very minimal.
- The model was able to minimize loss for x value output faster than y value output.

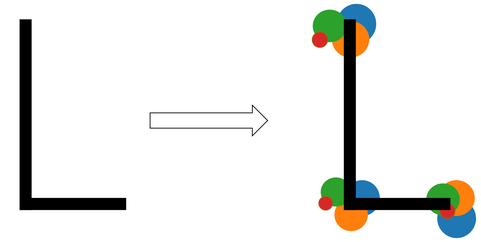




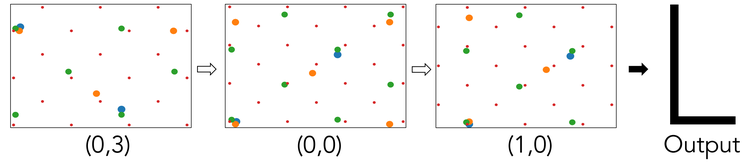
- When given a new image of a grid map the network hasn't seen before, the model gives its prediction and degree of confidence for both the x and y values associated with the grid map.

APPLICATIONS

- Simple objects can be represented as a set of locations while still retaining the fundamental structure of the object.



- By sequentially feeding the model grid maps to classify and using a script to place straight lines between the predicted x-y positions, we can capture the structure of simple objects.
- Below is an example of sequentially feeding the model three grid maps representing the locations (0, 3), (0, 0), and (1, 0) then placing straight lines in between the predicted outputs.



FUTURE WORK

- Create dataset on a larger space than 9x9 so objects can be represented more accurately.
- Place lines between any two points, not just points that are vertical or horizontal to one another.
- Represent more complex objects with grid maps.
- Test the position and scale invariance of objects represented by grid cells.
- Determine if objects can be represented and classified with scale and position invariance.

ACKNOWLEDMENT & REFERENCES

The author acknowledges the support of the Maseeh College of Engineering and Computer Science (MCECS) through the Undergraduate Research and Mentoring Program (URMP).

This work was supported by C-BRIC, one of six centers in JUMP, a Semiconductor Research Corporation (SRC) program sponsored by DARPA.

References

[1] Numenta. How grid cells represent location (image). Available from : *Frontiers.* <https://www.frontiersin.org/articles/10.3389/fncir.2018.00121/full>. (April 28 2019).
[2] Hawkins, Jeff, Marcus Lewis, Mirko Klukas, Scott Purdy, and Subutai Ahmad. "A framework for intelligence and cortical function based on grid cells in the neocortex." *Frontiers in Neural Circuits*12 (2019). doi:10.3389/fncir.2018.00121.